

CLAIMS

What is claimed is:

1. A method for depositing a binder liquid on build material at a particular location in a three-dimensional printer, comprising:
 - 5 determining a total amount of binder liquid to solidify the build material at the particular location;
 - determining the amount of a colored binder liquid to produce a desired color at the particular location; and
 - determining the amount of colorless binder liquid to be added to the colored binder liquid to obtain the total amount of binder liquid, the sum of all the binder liquids to be applied at the particular location, both colored and colorless, being made to equal a sufficient amount of total binder liquid to solidify the build material at the particular location of build material.
- 10 2. The method of Claim 1 further comprising depositing the total amount of color binder liquid and colorless binder liquid at the particular location.
3. The method of Claim 1 further comprising determining the amount of total binder liquid to bind the build material at the particular location of build material before any binder liquid is deposited on the build material.
- 20 4. The method of Claim 1 further comprising programming software instructions for determining the contributions of colored binder liquid and colorless binder liquid to bind the build material at the particular location.

5. The method of Claim 1 further comprising determining a second total amount of colored binder liquid and colorless binder liquid to bind the build material at another particular location in the three-dimensional printer.
6. The method of Claim 5 wherein the second total amount of colored binder liquid and colorless binder liquid approximates a sufficient amount of total binder liquid to bind the build material at the another particular location of build material.
7. An apparatus for fabricating a three-dimensional object by depositing a sufficient amount of a binder liquid needed to solidify build material at a particular location in the apparatus, comprising:
- a build chamber that can be filled with the build material;
 - a gantry mounted for displacement across the build chamber;
 - at least one printhead mounted on the gantry for depositing a binder liquid on the build material;
 - a first set of software instructions for determining a total amount of binder liquid solidify the build material at the particular location;
 - a second set of software instructions for determining a contribution of a colored binder liquid at the particular location of the build material to produce a desired color at the particular location; and
 - a third set of software instructions for determining the contribution of a colorless binder liquid to be added to the colored binder liquid at the particular location of the build material; and
 - a fourth set of software instructions for controlling the printhead to deposit the total amount of the colored binder liquid and colorless binder liquid, the total amount of colored binder liquid and colorless binder liquid approximating the amount of total binder liquid sufficient to bind the build material at the particular location of build material.

8. The apparatus of Claim 7 further comprising:

a feed reservoir having stored therein a supply of build material for forming the object; and

5 a vacuum pump coupled to the feed reservoir or to the build chamber to create an airflow through the feed reservoir or the build chamber, respectively.

9. The apparatus of Claim 8 further comprising a switch that allows airflow through the feed reservoir or the build chamber.

10. The apparatus of Claim 8 further comprising a valve that controls airflow through the build chamber during fabrication of the three-dimensional object, the valve being controlled by a controller.

11. A method of fabricating a three-dimensional object by depositing a predetermined amount of a binder liquid on build material at a particular location of the object, comprising:

15 determining a contribution of a colored binder liquid at a particular location of the build material needed to produce the desired color at the particular location;

determining a contribution of a colorless binder liquid at the particular location of the build material;

20 determining the total amount of colored binder liquid and colorless binder liquid sufficient to solidify the build material at the particular location, the total amount of colored binder liquid and colorless binder liquid not exceeding the predetermined amount of binder liquid at the particular location of build material; and

depositing the total amount of colored binder liquid and colorless binder liquid at the particular location.

- 5 12. An apparatus for fabricating a three-dimensional object comprising:
a feed reservoir having stored therein a supply of build material for forming the object;
a build chamber for receiving layers of the build material from the feed reservoir; and
a vacuum pump coupled to the feed reservoir to create an airflow through the feed reservoir.
- 10 13. The apparatus of Claim 12 wherein the vacuum pump is further coupled to the build reservoir.
14. The apparatus of Claim 13 further comprising a switch that selects airflow through the feed reservoir or the build chamber.
- 15 15. The apparatus of Claim 14 further comprising a valve to control airflow through the build chamber during fabrication of the three-dimensional object, the valve being controlled by a controller responsive to the switch.
16. The apparatus of Claim 15 wherein the controller includes software instructions.
17. The apparatus of Claim 12 further comprising a plenum that supports the build material and allows airflow therethrough.
- 20 18. A method of fabricating a three-dimensional object comprising:
providing a feed reservoir having stored therein a supply of build material for forming the object;

providing a build chamber for receiving incremental layers of the build material from the feed reservoir;

providing an overflow cavity for receiving an excess quantity of build material transferred from the feed reservoir but not received by the build chamber; and

creating an airflow through the feed reservoir or the build chamber.

19. The method of Claim 18 further comprising selectively creating an airflow through the feed reservoir or build chamber.

20. The method of Claim 18 further comprising selectively creating an airflow through the build chamber during fabrication of the three-dimensional object.

21. The method of Claim 18 further comprising supporting the build material by allowing airflow therethrough.

22. An apparatus for fabricating a three-dimensional object comprising:
a feed reservoir having stored therein a supply of build material for forming the object;
a build chamber for receiving layers of the build material from the feed reservoir; and
a vacuum pump coupled to the feed reservoir and to the build chamber to create an airflow through the feed reservoir or the build chamber in response to a switch.

23. The apparatus of Claim 22 wherein the switch is configured to be controlled by a user of the apparatus.

24. The apparatus of Claim 22 further comprising a valve that controls airflow through the build chamber during fabrication of the three-dimensional object, the valve being controlled by a controller responsive to the switch.
- 5 25. The apparatus of Claim 24 wherein the valve is controlled by a controller that includes software instructions.
- ~~26.~~ A method of printing a three-dimensional object, comprising:
depositing a first colored binder liquid on a bed of build material to form a first colored band along a first edge;
10 depositing a second colored binder liquid on the bed of build material to form a second colored band along a second edge; and
depositing colorless binder liquid on the bed of material between the first band and the second band.
27. The method of Claim 26, wherein the colorless band forms a tapered band.
- 15 28. The method of Claim 26, further comprising printing a higher concentration of the first colored binder liquid and a higher concentration of the second colored binder liquid at the tapered sections of the band.
- ~~29.~~ A computer-readable medium storing software instructions that generate commands for controlling at least one printhead as it prints a substance including colorant on a bed of build material to form a multi-colored three-dimensional
20 object, the software instructions including commands for printing the substance in bands extending from surfaces of the three-dimensional object into the object, the bands tapered at edges of the three-dimensional object to leave a non-colored section between adjacent bands.

30. The computer-readable medium of claim 29, wherein the software instructions further generate commands to print a higher concentration of colorant at the tapered sections of the bands.

31. A method for three-dimensional printing comprising the steps of:

5 with at least one printhead, depositing binder liquid onto a bed of build material to form sections of a three-dimensional object;

10 with at least one printhead, depositing a substance including colorant of a first color onto the bed of build material in a band extending from a first surface of the three-dimensional object into the object, wherein the band is tapered at an edge where the first surface meets an adjacent surface; and

15 with at least one printhead, depositing a substance including colorant of a second color onto the bed of build material in a band extending from the adjacent surface into the object, wherein the band is tapered at the edge where the adjacent surface meets the first surface to leave a non-colored section between the bands.

32. The method of claim 31, further comprising depositing the substances to form higher concentrations of colorant in the tapered sections of the bands relative to the remainder of the bands.

33. An apparatus for fabricating a three-dimensional object comprising:

20 a structural frame;

a build chamber supported by the frame, the build chamber being suited to be filled with a build material;

a gantry mounted for displacement across the build chamber;

at least one printhead mounted on the gantry; and

25 at least one cleaning element movable relative to the frame for cleaning the at least one printhead.

34. The apparatus of Claim 33 wherein the cleaning element is mounted to a support element of a cleaning assembly.
35. The apparatus of Claim 34 further comprising a deck supported by the frame, wherein the cleaning assembly further includes a device for raising and lowering the support element such that the at least one cleaning element extends above the deck in one position and extends below the deck in another position.
36. The apparatus of Claim 33 wherein the cleaning element includes a squeegee.
37. The apparatus of Claim 33 further comprising a nozzle that sprays the cleaning element with a liquid to clean the at least one cleaning element.
38. The apparatus of Claim 37 wherein the nozzle sprays the cleaning element while the cleaning element is moving.
39. The apparatus of Claim 37 wherein the liquid includes a binder liquid.
40. The apparatus of Claim 37 wherein the liquid includes water mixed with polyethylene glycol.
41. The apparatus of Claim 33, wherein the gantry is mounted for displacement across the build chamber along a slow axis, and further comprising at least four printheads mounted on the gantry for displacement along a fast axis, the printheads being offset to each other and further comprising at least four cleaning elements being offset along the fast axis to register with respective printheads.

42. A method for fabricating a three-dimensional object comprising:
providing a structural frame;
supporting a build chamber with the frame, the build chamber suited to
be filled with a build material;
- 5 providing a gantry for displacement across the build chamber;
mounting at least one printhead mounted on the gantry; and
mounting a cleaning element for cleaning the at least one printhead.
43. The method of Claim 42 further comprising moving the cleaning element above
10 a deck supported by the frame to clean the at least one printhead.
44. The method of Claim 43 further comprising moving the cleaning element below
the deck after cleaning the at least one printhead.
45. The method of Claim 44 further comprising spraying the cleaning element with a
liquid to clean the cleaning element with the cleaning element below the deck.
- 15 46. The method of Claim 45 further comprising spraying the cleaning element with a
binder liquid.
47. The method of Claim 45 further comprising spraying the cleaning element with
water mixed with polyethylene glycol.
48. The method of Claim 42, wherein the gantry is mounted for displacement across
20 the build chamber along a slow axis, and further comprising at least four
printheads mounted on the gantry for displacement along a fast axis, further
comprising offsetting the printheads along the slow axis and further comprising
at least four cleaning elements aligned with respective printheads.

49. An apparatus for fabricating a three-dimensional object comprising:
a build chamber that can be filled with a build material;
a gantry mounted for displacement across the build chamber along a slow axis; and
5 at least four printheads mounted on the gantry for displacement along a fast axis, the printheads being offset relative to each other.
50. The apparatus of claim 49, wherein the printheads print substances including colorants onto the build material.
51. The apparatus of claim 50, wherein the printheads are offset from adjacent
10 printheads by a fixed distance along the slow axis, and the printheads are advanced step-wise along the slow axis by the fixed distance.
52. The apparatus of claim 50, wherein a binder liquid is mixed with the colorant before depositing on the build material.
53. The apparatus of claim 49, wherein colorless binder liquid is deposited by each
15 of the printheads.
54. The apparatus of claim 53, wherein the printheads are offset from adjacent printheads by a fixed distance along the slow axis, and the printheads are advanced step-wise along the slow axis by a multiple of the fixed distance.
55. A method for three-dimensional printing comprising:
20 passing a plurality of printheads over a bed of build material along a fast axis, each of the printheads capable of depositing stripes as needed of a substance onto the build material in stripes, the stripes printed by the different

printheads being offset from one another along a slow axis, which is substantially perpendicular to the fast axis; and
advancing the plurality of printheads along the slow axis.

56. The method of claim 55, wherein the printheads print substances including colorants onto the build material.
57. The method of claim 56, wherein the printheads are offset from adjacent printheads by a fixed distance along the slow axis, and the printheads are advanced step-wise along the slow axis by the fixed distance.
58. The method of claim 56, further comprising mixing a binder liquid with the colorant before depositing on the build material.
59. The method of claim 55, wherein colorless binder liquid is deposited by each of the printheads.
60. The method of claim 59, wherein the printheads are offset from adjacent printheads by a fixed distance, and the printheads are advanced step-wise along the slow axis by a multiple of the fixed distance.
61. An apparatus for fabricating a three-dimensional object comprising:
a build chamber that can be filled with a bed of build material;
a plurality of printheads mounted for displacement across the build chamber;
at least one binder source external to the printheads; and
a plurality of conduits coupling each binder source with at least one printhead.

62. The apparatus of claim 61 wherein each binder source includes either a colorless binder liquid or a single colored binder liquid.
63. The apparatus of claim 62 wherein the colored binder liquid is formed by premixing a colorless binder liquid with a colorant outside the apparatus to form the colored binder liquid.
64. The apparatus of claim 62 wherein the colored binder liquid is formed by mixing a colorless binder liquid with a colorant inside the apparatus to form the colored binder liquid.
65. The apparatus of claim 62 wherein each binder source that includes a colored binder liquid includes a color distinct from that of other colored binder liquid.
66. The apparatus of claim 65 wherein the apparatus includes a first printhead coupled to the colorless binder liquid, a second printhead coupled to a cyan colored binder liquid, a third printhead coupled to a yellow colored binder liquid, and a fourth printhead coupled to a magenta colored binder liquid.
67. The apparatus of claim 66 further comprising a fifth printhead coupled to a black colored binder liquid.
68. The apparatus of claim 62, further comprising a gantry mounted for displacement across the build chamber along a slow axis, the printheads being aligned on the gantry in at least two rows extending parallel to a fast axis or slow axis.

69. The apparatus of claim 68, wherein printheads that are coupled with a colored binder liquid are paired in the same row with a printhead coupled with a colorless binder liquid.
70. The apparatus of claim 61, further comprising a gantry mounted for
5 displacement across the build chamber along a slow axis, each of the printheads being positioned at a coordinate along the slow axis that is distinct from that of the other printheads.
71. The apparatus of claim 61, wherein the binder sources supply the binder liquid
10 to each of the printheads by conduits, the conduits including circulation loops that allow the binder liquid to be circulated within the conduit.
72. The apparatus of claim 61, further comprising computer-readable memory
15 storing software instructions for issuing commands to the printheads, wherein the software instructions generate commands that instruct the printheads to deliver the colored binder liquid in bands extending from a surface of the object into the object, the bands being tapered at an edge of the object to leave a non-colored section extending into the object from the edge.
73. The apparatus of claim 72, wherein the software instructions generate commands that instruct the printheads to print a higher concentration of the colored binder liquid at the tapered section of the band.
- 20 74. The apparatus of claim 61, further comprising computer-readable memory storing software instructions for issuing commands to the printheads and a gantry mounted for displacement across the build chamber along a slow axis, wherein the software instructions control the length of each advancement of the gantry along the slow axis as a function of whether the printheads are depositing

the colored binder liquid, the software generating commands to advance the gantry a greater distance along the slow axis if all of the printheads are depositing a colorless binder liquid or if all of the printheads are printing colored binder liquid of the same color.

- 5 ~~75.~~ A method for fabricating a three-dimensional object comprising:
 providing a build chamber that can be filled with a bed of build material;
 mounting a plurality of printheads for displacement across the build
 chamber;
 providing at least one binder source external to the printheads; and
10 coupling each binder source with at least one printhead through a
 plurality of conduits.
76. The method of claim 75 wherein each binder source includes either a colorless
binder liquid or a single colored binder liquid.
- 15 77. The method of claim 76 further comprising premixing a colorless binder liquid
with a colorant to form the colored binder outside the apparatus.
78. The method of claim 76 further comprising mixing a colorless binder liquid with
a colorant inside the apparatus to form the colored binder liquid.
79. The method of claim 76 wherein each binder source that includes a colored
binder liquid includes a color distinct from that of other colored binder liquid.
- 20 80. The method of claim 79 further comprising coupling a first printhead to the
colorless binder liquid, coupling a second printhead to a cyan colored binder
liquid, coupling a third printhead to a yellow colored binder liquid, and coupling
a fourth printhead to a magenta colored binder liquid.

81. The method of claim 80 further comprising coupling a fifth printhead to a black colored binder liquid.
82. The method of claim 76, further comprising mounting a gantry for displacement across the build chamber along a slow axis, the printheads being aligned on the gantry in at least two rows extending parallel to a fast axis or slow axis.
83. The method of claim 82, wherein printheads that are coupled with a colored binder liquid are paired in the same row with a printhead coupled with a colorless binder liquid.
84. The method of claim 79, further comprising mounting a gantry for displacement across the build chamber along a slow axis, each of the printheads being positioned at a coordinate along the slow axis that is distinct from that of the other printheads.
85. The method of claim 75, wherein the binder sources supply the binder liquid to each of the printheads by conduits, the conduits including circulation loops that allow the binder liquid to be circulated within the conduit.
86. The method of claim 75, further comprising delivering the colored binder liquid in bands extending from a surface of the object into the object, the bands being tapered at an edge of the object to leave a non-colored section extending into the object from the edge.
87. The method of claim 86, further comprising printing a higher concentration of the colored binder liquid at the tapered section of the band.

88. The method of claim 76, further comprising mounting a gantry for displacement across the build chamber along a slow axis, and controlling the length of each advancement of the gantry along the slow axis as a function of whether the printheads are depositing the colored binder liquid, the gantry advancing a greater distance along the slow axis if all of the printheads are depositing a colorless binder liquid or if all of the printheads are printing colored binder liquid of the same color.
89. An apparatus for fabricating a three-dimensional object comprising:
a container for containing a binder liquid mixed with a colorant to create a colored binder liquid;
a conduit for delivering the colored binder liquid to a printhead, the printhead depositing the colored binder liquid onto a bed of build material; and
a circulation loop for circulating the colored binder liquid in the conduit.
90. The apparatus of claim 89, further comprising:
a colorless binder liquid that is delivered to the conduit; and
a valve for diverting the flow of colored binder liquid through the conduit to the printhead.
91. The apparatus of Claim 90, further comprising a second circulation loop in the conduit for circulating the colorless binder liquid in the conduit.
92. The apparatus of claim 90, further comprising a valve for stopping the delivery of the colored binder liquid through the printhead and for allowing circulation of the colorless binder liquid through the circulation loop.

93. The apparatus of claim 92, wherein the valve stops the delivery of the colorless binder liquid through the printhead and allows circulation of the colored binder liquid through the circulation loop.
- 5 94. The apparatus of claim 89, further comprising a valve in the conduit which allows waste colored binder liquid to exit the conduit.
95. The apparatus of claim 90, further comprising a valve in the conduit which allows waste colorless binder liquid to exit the conduit.
- 10 96. A method for three-dimensional printing comprising the steps of:
mixing a binder liquid with a colorant to create a colored binder liquid;
delivering the colored binder liquid to a printhead with a conduit;
depositing the colored binder liquid with the printhead onto a bed of
build material; and
circulating the colored binder liquid through a first circulation loop in the
conduit.
- 15 97. The method of claim 96, further comprising delivering colorless binder liquid from an external binder liquid source to the conduit and using a valve to divert the flow of colored binder liquid through the conduit to the printhead.
98. The method of Claim 97, further comprising circulating the colorless binder liquid through a second circulation loop in the conduit.
- 20 99. The method of claim 97, further comprising:
stopping the delivery of the colored binder liquid through the printhead;
circulating the colorless binder liquid through the circulation loop; and
delivering the colorless binder liquid through the printhead.

100. The method of claim 97, further comprising:
stopping the delivery of the colorless binder liquid through the printhead;
circulating the colored binder liquid through the circulation loop; and
then
5 delivering the colored binder liquid through the printhead.
101. The method of claim 96, further comprising providing a valve in the conduit
which allows waste colored binder liquid to exit the conduit.
102. The method of claim 97, further comprising providing a valve in the conduit
which allows waste colorless binder liquid to exit the conduit.
- 10 103. An apparatus for fabricating a three-dimensional object comprising:
a frame;
a build chamber mounted to the frame and suited for being filled with a
build material;
a chute defining an overflow cavity, the chute being positioned to receive
15 overflow build material from the build chamber;
a removable collection chamber coupled with the chute to receive build
material that passes through the chute.
104. The apparatus of claim 103, further comprising a blower coupled to the chute to
enable the blower to draw air through the chute.
- 20 105. The apparatus of claim 104, wherein the removable collection chamber is
positioned between the blower and the chute.

106. The apparatus of claim 103, further comprising a feed chamber mounted to the frame, the feed chamber suited for being filled with a supply of build material to be delivered to the build chamber.
107. The apparatus of claim 103, wherein the removable collection chamber is in the form of a bucket that can be used to pour the collected build material back into the feed chamber.
108. The apparatus of claim 107, wherein the bucket includes an extended lip to facilitate pouring of collected build material.
109. The apparatus of Claim 103, further comprising an optical sensor for sensing when the removable collection chamber contains a predetermined amount of build material.
110. A method for reclaiming build material in a three-dimensional printer comprising the steps of:
- filling a feed chamber with build material;
 - transporting the build material from the feed chamber to a build chamber;
 - printing binder liquid onto the build material in the build chamber;
 - removing excess build material to a collection chamber; and
 - returning the excess build material from the collection chamber to the feed chamber.
111. The method of claim 110, wherein the excess build material is returned to the feed chamber by removing the collection chamber and pouring the excess build material into the feed chamber.

112. The method of claim 110, wherein the excess material is transported from the build chamber through a chute into the collection chamber.
113. The method of claim 112, further comprising using a blower to draw air through the chute and into the collection chamber, the collection chamber being
5 positioned upstream from the blower.
114. The method of Claim 110, further comprising sensing, with an optical sensor, when the removable collection chamber contains a predetermined amount of build material.

112. The method of claim 110, wherein the excess material is transported from the build chamber through a chute into the collection chamber.

113. The method of claim 112, further comprising using a blower to draw air through the chute and into the collection chamber, the collection chamber being
5 positioned upstream from the blower.

114. The method of Claim 110, further comprising sensing, with an optical sensor, when the removable collection chamber contains a predetermined amount of build material.